UV Sentry: A Collaborative Approach to Creating a Collaborative System

The 2011 CINT Team

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Overview

- Background
  - Centers for Innovative Naval Technology (CINT)
  - UV Sentry Concept
  - Proposed Scenario
- Summer Objectives
- Discussion of Results
  - Developed CONOPS
  - Platform
  - Autonomy
  - Communications
  - Human-Machine Interfacing

Background: Centers for Innovative Naval Technology

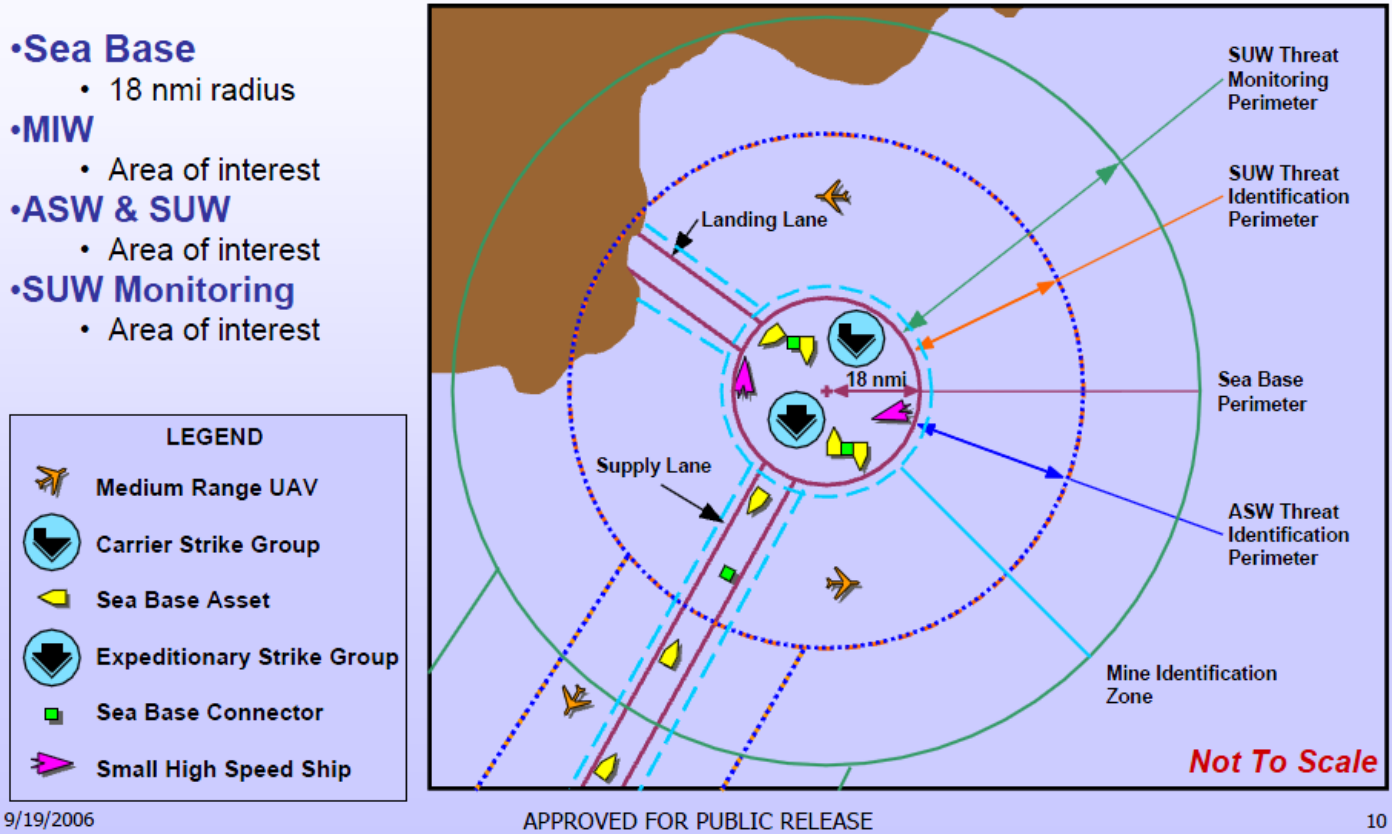
- Underlying Structure:
  - Single Overall Project
  - Student Interns at Multiple Centers
    - NREIP
    - SMART
  - Mentors and Advisors at Each Center
- Objectives:
  - Concept Development and Exploration
  - Cross Lab Collaboration
  - Students Exposure to Multidisciplinary Team Projects

Background: UV Sentry

- Multiple Unmanned Vehicle System
  - Autonomous Collaboration
  - Heterogeneous Mix of Vehicles
- Force Protection Role
  - Expanded Situational Awareness
  - Reduced Response Times
  - Flexible Mission Profiles

Background: UV Sentry

- Originally Envisioned for Sea Base Protection



Background: UV Sentry

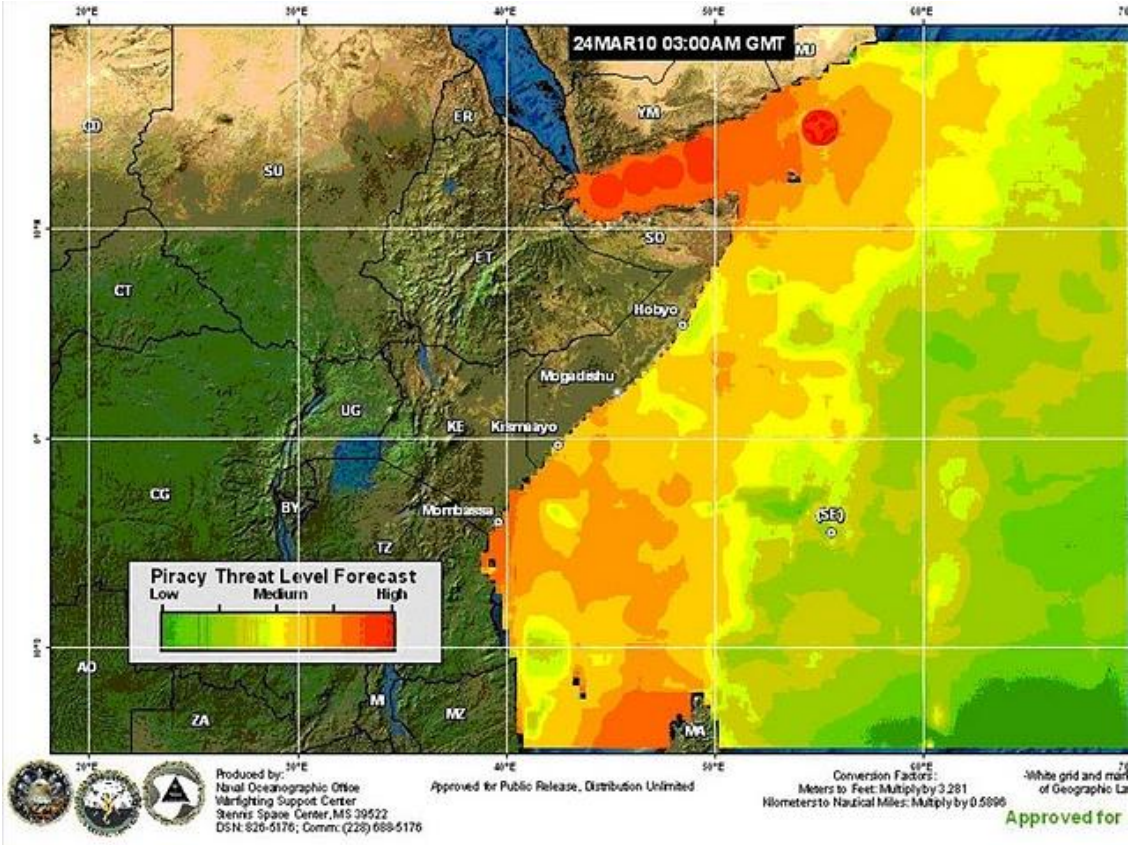
Several Identified Missions:

- Maritime Facility Protection
  - Persistent, long endurance, asset-limited surveillance and tracking
- Counter Drug Operations:
  - Persistent, long endurance, wide-area surveillance and tracking
- Maritime Security/ Anti-Piracy
  - Persistent, long endurance, wide-area surveillance and warning
- Maritime Domain Awareness
  - Persistent ISR, automated data fusion, autonomous mission planning and task allocation

Background: Anti-Piracy Scenario

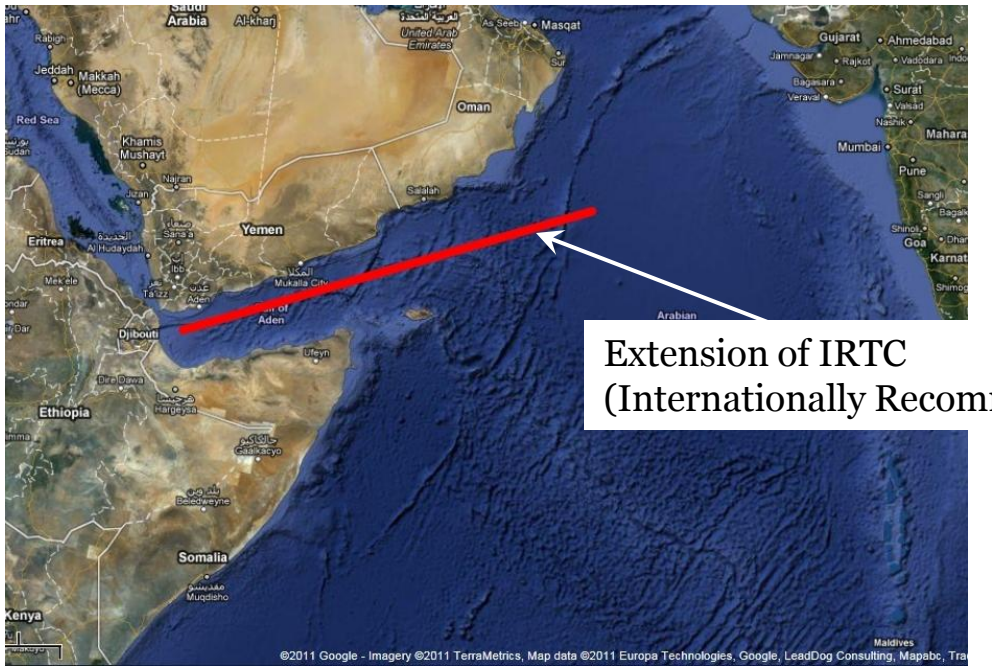
- 219 attempted pirate attacks off the coast of Somalia in 2010
- Greater than $80M was paid out in ransom
- Costs maritime industry $1-16B

  (Peter Chald, Rand Corp 2009)
- Number of attacks and dollars paid out in ransom increasing each year



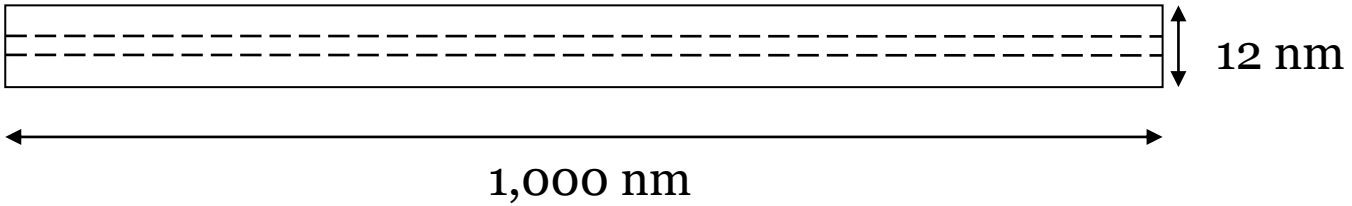
Background: Anti-Piracy Scenario

Area of Protection



Extension of IRTC
(Internationally Recommended Transit Corridor)

Detail of protection area



Background: Anti-Piracy Scenario

- Typical Convoy Based Force Protection Schemes Not Viable:
  - 33,000 ships pass through per year
  - 3 days to transit area of protection
  - 300 ships in area of protection at one time
  - 15 minute response times
- Major Challenges
  - Reduction in Response Time
  - Increased Situational Awareness

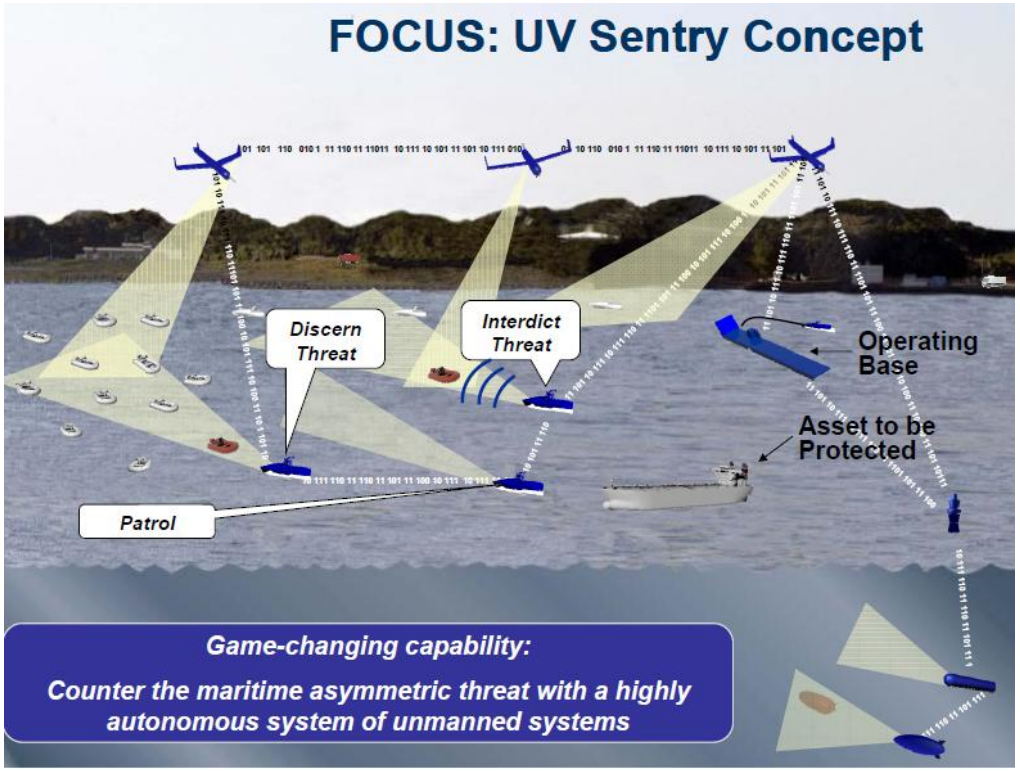
Summer Objectives

- CINT:
  - Provide Stimulating, Challenging, and Educational Problems for the Summer Students
  - Foster Interdisciplinary, Cross-Warfare Center Teams
  - Establish a model from which future CINT efforts could draw.
- UV Sentry
  - Evaluate Technical Feasibility of Concept
  - Identify Technologies of Interest for Future Study

Summer Objectives: Topic Focuses

- Platform Objectives:
  - USV design to meet needs of scenario
  - Explore small craft design without need for onboard human operator
- Autonomy Objectives:
  - Identify enabling technology and methods for the autonomous, decentralized operation of multiple, heterogeneous unmanned vehicles
  - Focus Areas:
    - Real-time tasking
    - Machine learning
    - Autonomous target identification and classification
- Communication Objective:
  - Identify requirement drivers for the UV Sentry communication system
- Human-Machine Interaction Objectives
  - Identify Human-Machine Interface (HMI) requirement drivers
  - Explore the implications related to increasing the level of autonomy in system

Results: System CONOPs



General CONOPs

- Leverage Platform Capabilities
  - UAVs – Comms relays and broad area surveillance
  - USVs – Local recon and threat interdiction
  - UUVs – Discrete surveillance
- Zonal Coverage
- Human in-the-loop Control Systems

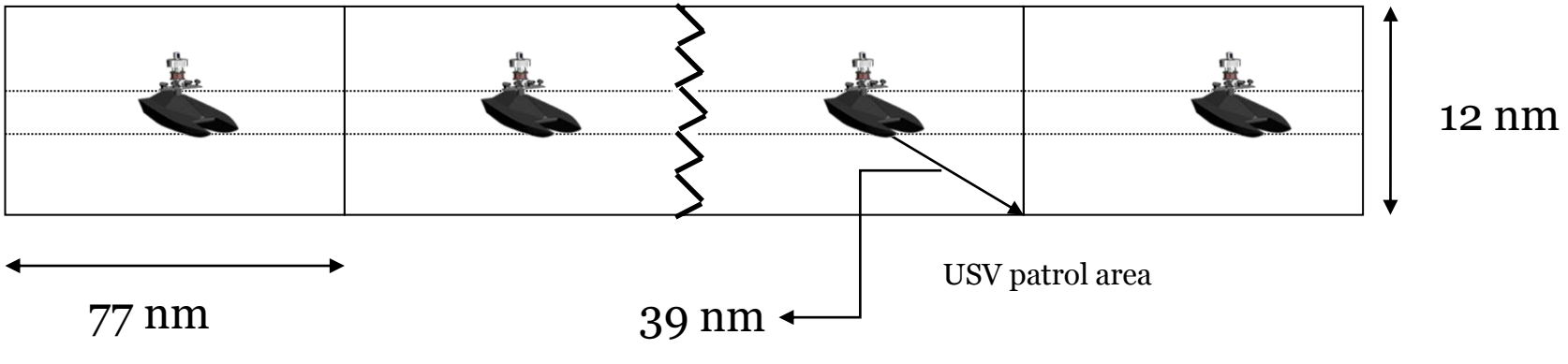
UxV System Operational View

Remote Supervisory Control

OV 1 Diagram

Results: Platform CONOPs

- Deployed & serviced by Service Ship
- Loiter until pirate threat detected
  - Each USV guards a 77x12 nm area
  - 13 USVs needed for complete coverage
  - 5 days between servicing
- Intercept pirate threat (sprint up to 39 nm)
  - Provide ISR
  - Delay, Deter or Monitor/Follow



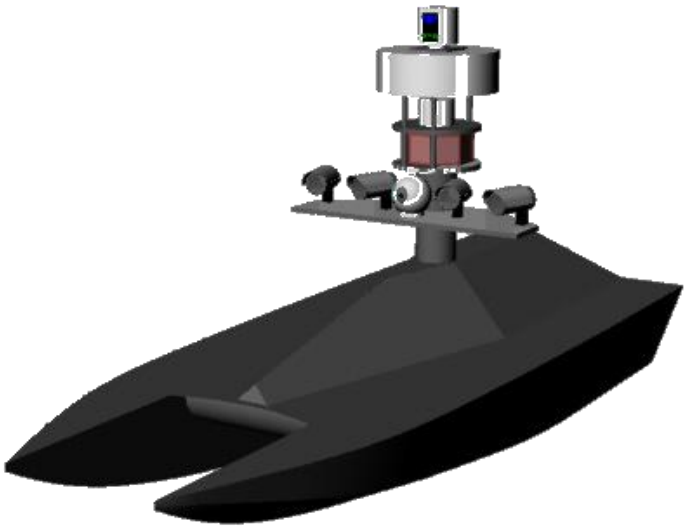
Results: USV Requirements

- Endurance: 6 days (1 day buffer)
- Speed: 40 knots sprint speed
  - Allows for 60 minute or less response time anywhere in zone
- Sea State (S.S.)
  - Operable in S.S. 4 (2.5m waves)
  - Survivable in S.S. 7 (9m waves)
- Loiter in up to 1.5 knot current

Hydrofoil Supported Catamaran

Length Overall	11 m
Beam	4.7 m
Draft	0.8 m
Displacement	7.8 tonnes
Speed (S.S. 4)	40 knots
Duration	6 days
Installed Power	898 kW

Characteristics



Isometric View

Results: Group Autonomy

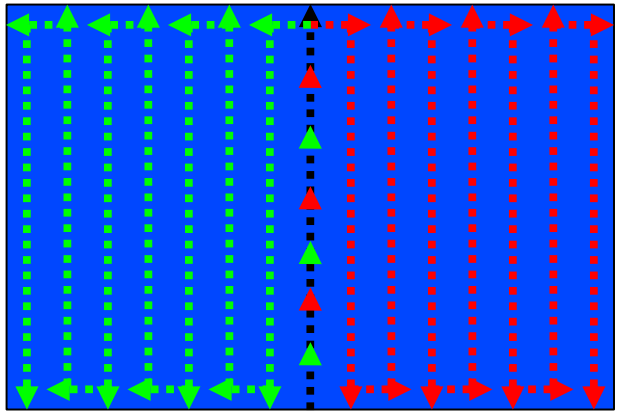
- Game Theory (GT) is used to determine the **Group Mode**.
  - Every possible action is given an objective function.
  - Each function is evaluated given the current state of the environment.
  - The highest function value is chosen for the next action.
- Market-Based Tasking (MBT) is used to determine **Individual Tasks**.
  - MBT uses an auctioning system to optimally redistribute Tasks.
  - Periodically each UV auctions it current task.
  - Participants place bids on the task using a personal cost-benefit function.
  - The highest bid wins the auction and is assigned the task.

Results: Machine Learning

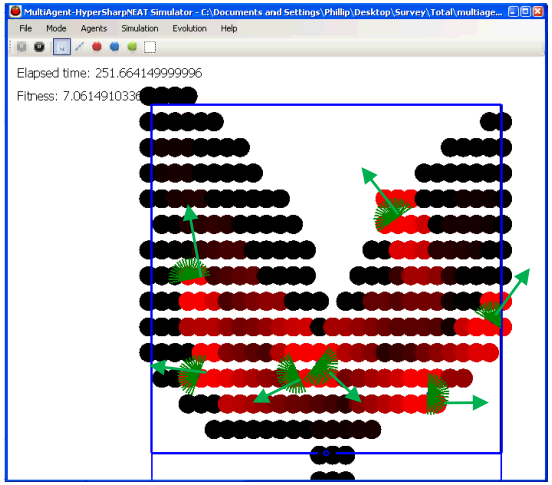
Big Picture: Benefits of Machine Learning:

- Machine learning leverages cheap computational power rather than expensive man-power
- Learned policies can compete with or exceed the performance of human-designed policies
- Learning can provide robustness and features such as scalability
- Learning algorithms are domain independent

Results: Machine Learning



Scripted Search Pattern



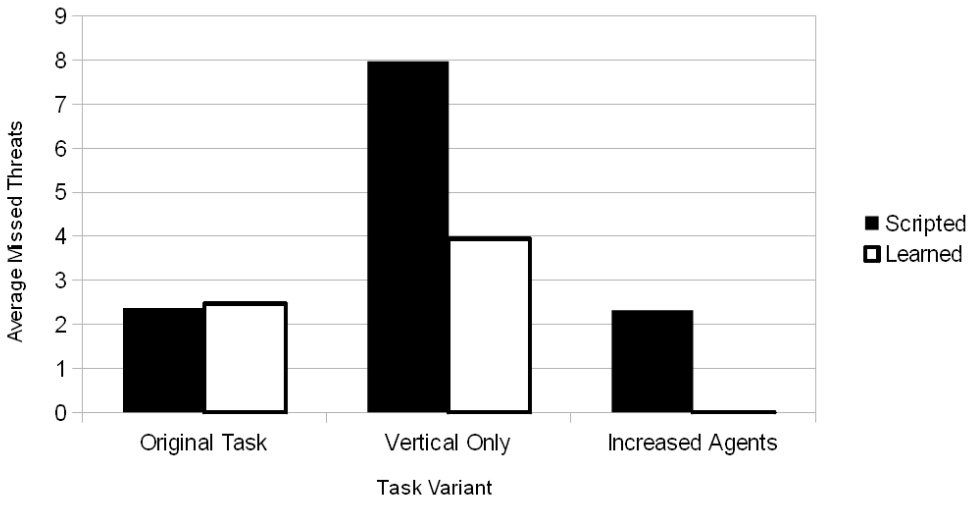
Learn Search Behavior

Search Patterns

Patrol Training Domain

- 7 'USV's
  - 3 nm sensors
  - 25 knot speed
- Potential 'pirate' threats
  - Randomly appear along edges of operational area
  - Traverse a straight line to a random point on opposite edge
  - 10 knot speed
- Learned policy 'USV's must come within half sensor range to remove threat
  - Hand designed parallel search is relaxed to full sensor range

Results: Machine Learning

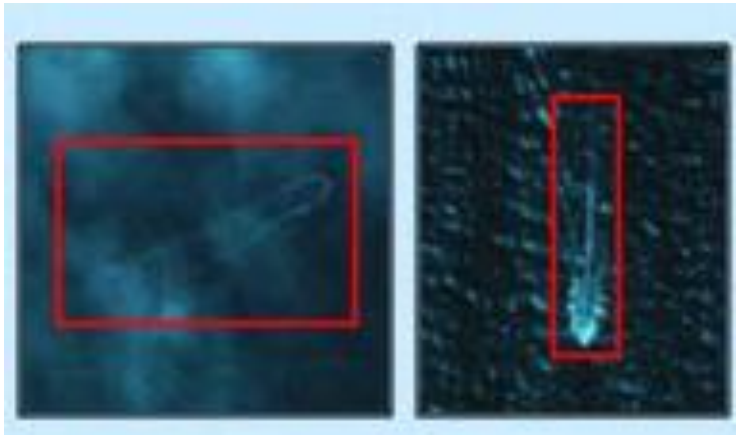


- Learned policy competitive with scripted policy that incorporates domain knowledge
- Learned policy more robust to changes in the domain
- Learned scales performance with number of agents

Results: Object Recognition

Rapid Image Exploitation Resource (RAPIER)

- What is RAPIER?
  - Framework for processing satellite imagery
  - Automatically detect targets and analyze imagery
- Allows one to create new algorithms to plug into RAPIER (airplanes, vehicles, roads, etc.) – currently used for ship detection
- Handles variety of data sources : SAR, EO, Multispectral, IR, etc
- Large Computational Loads
  - Increased Preprocessing
  - High Bandwidth

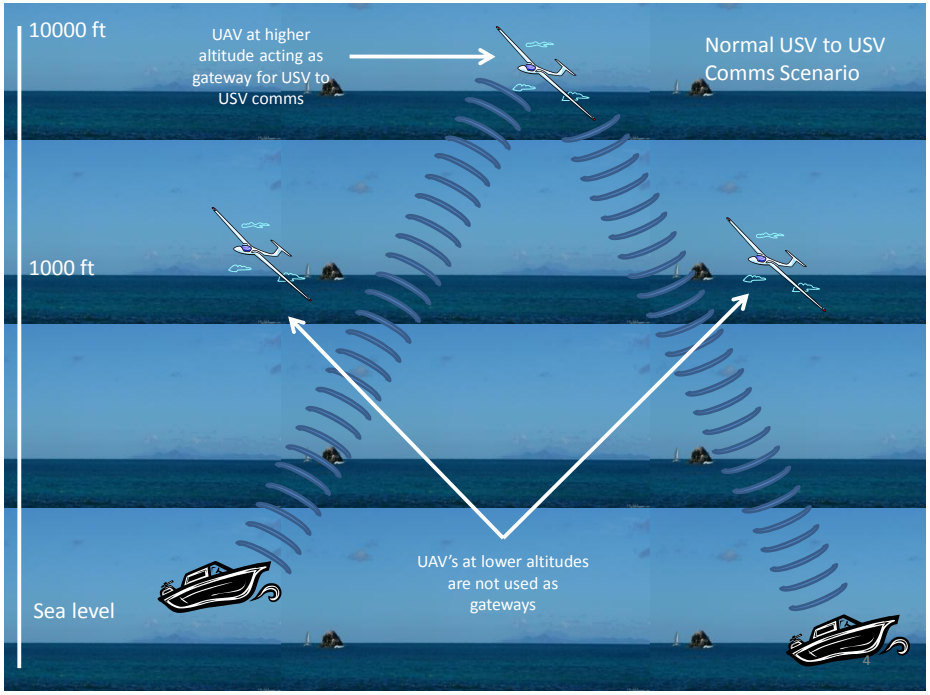


Advanced Algorithms Detect Ships behind Clouds and in Rough Seas

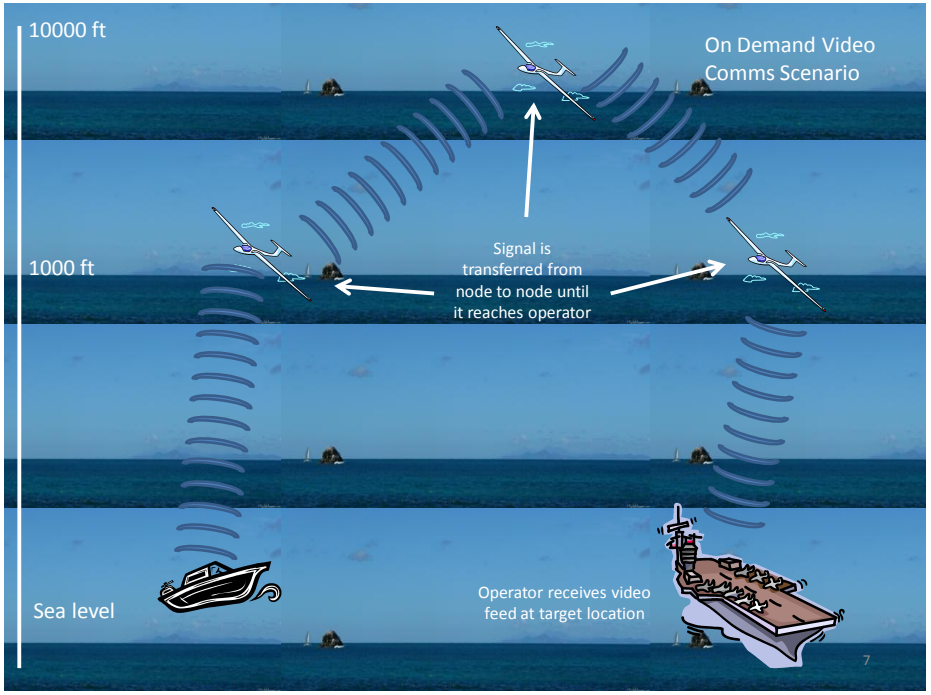
Results: Communication Systems

- Challenges:
  - Variable Bandwidth Loading with High Peak Loading
  - Large Distributed Network without Set Architecture
- Proposed Solution:
  - Ad Hoc Network Structure
  - Communication Pathways reconfigure based upon bandwidth demands

Results: Communication Systems



Low Bandwidth Network Concept

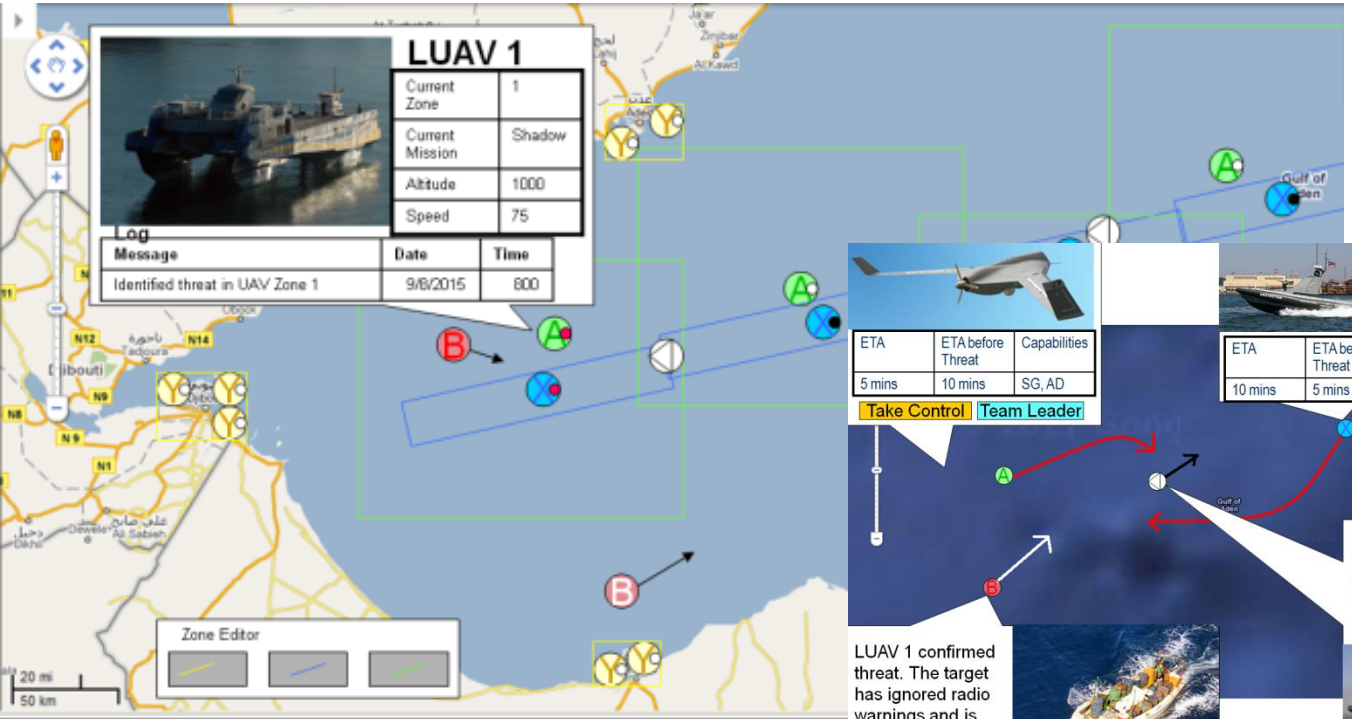


High Bandwidth Network Concept

Results: Human Factors

- Automation Level Concerns
  - Too much automation under utilizes users, reducing their situation awareness and overall system performance
  - Too little automation overloads users, reducing their situation awareness and overall system performance
  - **Balance**
- Human – Machine Interface Design Concerns
  - Focus on the users and their tasks, not the technology
  - Consider function first, presentation later
  - Conform to the users' view of the task
  - Do not complicate the users' task
  - Promote learning
  - Deliver information, not just data
  - Design for responsiveness
  - Try it out on users, then fix it

Results: Human – Machine Interface



Mission Log

Message	From	To	Action	Date	Time
Identified threat in UAV Zone 1	LUAV 1	System	USV 3 moving to battle formation	9/8/2015	800
HVA 1 leaving USV Zone 3 to USV Zone 2	USV 3	USV 2	None	9/8/2015	730
Potential threat identified in UUV Zone 4	UUV 4	LUAV 6	LUAV 6 moving to shadow potential threat	9/8/2015	700
All clear in UAV Zone 4	LUAV 4	System	None	9/8/2015	645
USV 1 lost comms due to high seas	USV 1	System	USV 1 moving to calmer waters	9/8/2015	630

Results: Summary

- A large number of the necessary pieces of UV Sentry are being actively developed for use in other programs
  - Machine Learning
  - Object Detection
  - Communication Networks
  - Single Vehicle Autonomy
  - HMI
- The viability of UV Sentry is dependent upon the integration of all of the technical components

Questions

Thanks to Our Sponsors:
Bob Brizzolara (ONR) and Kelly Cooper (ONR)